ADDRESS

Delivered by the President, Sir Robert S. Ball, LL.D., F.R.S., on presenting the Gold Medal to Mr. F. McClean. LL.D., F.R.S.

THE Council have this year bestowed the Gold Medal of the Royal Astronomical Society on our distinguished Fellow, Mr. Frank McClean, in recognition of his important contributions to spectroscopic astronomy. In making this award, the Council have specially desired to mark with their approbation the zeal, the patience, and the success with which Mr. McClean has carried through his splendidly conceived scheme of photographing the spectra of all stars down to a certain limit of brightness over the whole surface of the celestial sphere.

To set before the Society some account of those researches which have been instrumental in deciding the Council to award to Mr. McClean the highest distinction in their power, I commence with a brief description of some of the earlier works of our medallist, the success of which induced him to undertake the great celestial survey that he has recently completed.

In 1890 November, Mr. McClean submitted to the Royal Astronomical Society an elaborate series of comparative photographs of the spectra of the High Sun and the Low Sun. This paper was accompanied by an Atlas of Plates, which constitute a beautiful piece of astronomical work.

The apparatus employed in this investigation consisted essentially of a heliostat commanding a large extent of the horizon, by which the solar light was reflected into a telescope parallel to the polar axis. The object-glass of this telescope had a focal length of 98 inches, and the aperture was stopped down to 4 inches. A right-angled prism near the focus reflected the solar image horizontally into the spectroscope, which consisted of a pair of collimating and observing telescopes, each of 2 inches aperture. These are fixed at an inclination of 16° 30′, and at their intersection is a Rowland grating. Many interesting details are recorded with regard to the absorption screens that Mr. McClean found useful for the different parts of the spectrum.

The Atlas of Plates contains spectra of the High Sun, when

the altitude was as much over 45 degrees as possible, and of the Low Sun, when the altitude was under $7\frac{1}{2}$ degrees. The elastic force of aqueous vapour present in the atmosphere, on each occasion, has been duly recorded. The whole length of the spectrum has been divided into thirteen sections corresponding to Ångström's scale. In the production of the Atlas the original negatives have been magnified about $8\frac{1}{2}$ times. Each section is thus 35 cms. long, the width of the spectrum being nearly 6 cms. To facilitate the comparison between the spectra of the Sun when high, and the Sun when low, the photographs are placed in juxtaposition, so that corresponding lines are continuous.

An inspection of these remarkable plates brings out in a striking manner the varied effects of atmospheric absorption on the light of the spectrum, in accordance with the variations of solar altitude. Mr. McClean divides the groups of lines which are specially under atmospheric influence into two classes. Firstly, there are groups in which the majority of the lines grow uniformly darker as the Sun approaches the horizon. Secondly, there are groups in which individual lines become exceptionally prominent in the spectrum of the Low Sun, these effects being specially noticeable when there is much moisture in the air. Among the groups of the first class we may mention those about A, as well as those about B, while among many instances of the second class, the well-known groups near D form specially remarkable features in Mr. McClean's plates. It will, of course, be understood that these photographs are not put forward for the purpose of determining any fundamental measurement. "They are," to use the author's own words, "only suitable for the identification of groups of lines, and for filling in the details between standard lines whose wave lengths have been determined by direct observations with proper instruments."

Another piece of important work which has to be classed among the preliminary labours of our medallist is his study of the comparative photographic spectra of the Sun and the metals. In a second Atlas, on about the same scale as that to which I have just referred, two fine series of photographs are contained. The first series comprises the metals of the Platinum group, and exhibits, in six sections, the spectra of iron, platinum, iridium, osmium, palladium, rhodium, ruthenium, gold and silver.

The second series contains elements of the Iron-Copper group, and presents, in six sections, the spectra of iron, manganese, cobalt, nickel, chromium, aluminium, copper.

The original negatives were taken with a Rowland plane grating, ruled with 14,438 lines in an inch, and with an observing telescope of about 36 inches focal length. These negatives were then enlarged about $8\frac{1}{2}$ times, and mounted in juxtaposition, so that corresponding lines of each spectrum form continuous vertical lines on the plate.

The sections into which the spectra have been divided, like those of the photographs of the solar spectrum already referred

to, have been arranged to accord with the well-known divisions of Ångström's solar spectrum. The student will find it an additional convenience that the scale adopted by Mr. McClean is also very nearly that of Ångström's map. The top and bottom of every plate are bounded by the solar spectrum, while immediately inside, at each end, is the iron spectrum obtained by sparking through air. Between the two iron spectra thus conveniently placed for comparison the bulk of the plate contains the spectra of the other metals. In the case of the Platinum group there are eight of these intermediate metals.

In the series of plates illustrating the Iron-Copper group the iron spectrum, as before, is placed immediately inside the solar spectrum, both at the top and the bottom, and the six other elements provide the intervening spectra. A striking feature on these plates is afforded by the broad lines and bands extending vertically down the plate which are due to the atmosphere. This spectrum is, of course, necessarily introduced when the induction spark is taken between metal electrodes in the air. With reference to these spectra, I cannot do better than quote Mr. McClean's own words :

"Before the true spectra of the metals can be arrived at, it is necessary to further eliminate the lines due to various impurities in the specimens of the metals employed as electrodes. Iron appears in the spectrum of aluminium, and to a less degree in other spectra. Calcium is almost universally present, and becomes especially prominent throughout Section I. Its principal lines run with varying strength across nearly every spectrum, and coincide with marked groups of lines in the solar spectrum. The calcium spectrum appears most strongly in osmium and cobalt. The principal barium lines are also present in osmium, and its complete spectrum is no doubt present in Section I."

"The beautiful fluting lines in Section IV. of the aluminium spectrum is attributed by Thalén to the oxide of aluminium formed in the aureole of the induction spark. The similar well-defined but less-marked fluting which occurs in many of the spectra in Section I. must be due to one of the constituents of the air. It cannot be due to calcium, for it is prominent in metals where calcium is absent."

But the chief work of Mr. McClean's scientific career, and the work which has mainly influenced your Council in awarding to him the Gold Medal of the Royal Astronomical Society, has been his great spectroscopic survey of all the brighter stars in the heavens. The project which Mr. McClean formed, and which he succeeded in accomplishing, was to obtain a photograph of the spectrum of every star not less bright than $3\frac{1}{2}$ magnitude in both celestial hemispheres.

His first task was to effect a partition of the celestial sphere into regions which should be convenient for reference, while at the same time the lines of partition should be those naturally

suggested by the character of the research which was to be undertaken. The ordinary subdivision into constellations was here, at least, quite unsuitable.

Mr. McClean somewhat daringly abandoned the celestial Equator when he required to effect the prime partition of the celestial sphere into two hemispheres. The sublime conception which each bright starlight night suggests to the reflective observer was adopted by your medallist. He took as his fundamental great circle that which as nearly as possible conforms to the path of the Galaxy. We are therefore to understand in these researches that the celestial pole is no longer the pole of the meridian astronomer or the navigator. It is, indeed, the true sidereal pole, the point nearly 90 degrees from the Galaxy; it is the pole of the Milky Way.

If a circle be drawn at a radius of 60 degrees from the North Galactic Pole, we obtain the first of Mr. McClean's partitions of the sphere; the area comprised within that segment is, of course, one-fourth of the entire spherical surface. Another fourth of the area would be comprised between this circle and the fundamental great circle, which we may perhaps describe as the Galactic Equator. The hemisphere containing the south pole of the Galactic Circle is to be similarly divided into a polar cap of 60 degrees radius and a zone bordering the equator 30 degrees broad. Thus the entire sphere is divided into four regions of equal extent. To carry the partition yet one stage further, a plane of section has been drawn through the Galactic axis. The choice of this plane was determined by the necessity for a convenient distinction between the celestial regions easily seen from stations in the Northern Hemisphere and those which required an observer in the Southern Hemisphere.

The two North Polar lunes are referred to by the symbols A and AA, the South Galactic Polar lunes are D and DD, the northern zones adjoining the Equator are B and BB, and the southern zones adjoining the Equator are C and CC.

As the scheme contemplated by Mr. McClean embraced a survey of the whole heavens, it was necessary to divide it into two parts; an observing station was therefore required in each hemisphere. The survey of the Northern Hemisphere was naturally conducted from the Observatory at Mr. McClean's residence at Rusthall, Tunbridge Wells; for the study of the Southern Hemisphere Mr. McClean proceeded to the Cape of Good Hope, and there availed himself of the assistance kindly rendered to him by Dr. David Gill at the famous Observatory over which Her Majesty's Astronomer so worthily presides. It is to this great and important work that I now invite your attention.

In both hemispheres alike Mr. McClean has found it necessary to introduce a classification of the spectra of the stars into a series of divisions as far as possible parallel to the types long associated with the name of Secchi. The first of the types described by Secchi has been subdivided for the present work

into three divisions, and then Secchi's second, third, and fourth types are identified respectively with the fourth, fifth, and sixth divisions used by Mr. McClean.

Division I. includes all stars whose spectra are characterised by possessing lines similar to those yielded by what Mr. McClean designates as Cleveite gas, in addition to the lines of Hydrogen. It has been found necessary to subdivide still further this division, inasmuch as the spectra of some of the stars which have to be included in the first division show other special lines in addition to those already mentioned. A comparison of the spectra of these stars with Campbell's photograph of the bright-lined spectrum of the great nebula in *Orion* has proved very instructive. Mr. McClean remarks that the general coincidence of the lines in the photograph of the nebula with the lines in the photographs of the stars of the first division leaves little doubt as to the close connection between stars of this denomination and the nebulæ specially designated as gaseous.

A remarkable parallelism between the distribution of the Helium stars of Division I. and the gaseous nebulæ must not be overlooked. Here we at once realise the special advantage of that form of division of the celestial sphere which has been adopted. By comparing the Table of Gaseous Nebulæ in Frost's edition of Scheiner's *Spectroscopy* with the list of the stars characterised by the Helium spectrum, a remarkable analogy is manifest. This is illustrated by the figures here shown :—

	Regions.			
	A.	B.	C.	D.
Gaseous nebulæ	3	7	16	6
Stars of Division I.	3	6	17	3

The second division in Mr. McClean's sidereal classification contains those stars which have spectra of the Hydrogen type. In this class of star the Hydrogen exhibits its full development, both in the strength of the individual lines and in the number in which they are present. The beautiful ultra-violet series of lines are a special feature of such spectra. The third and last of the separate divisions, which together make up Secchi's Type I., contain stars of the Hydrogen-Iron type, in some of which the iron is more fully displayed than it is in others. The fourth division recognised by Mr. McClean, equivalent as it is to Type II. according to Secchi, includes stars which have spectra of a solar character, while the fifth and the sixth divisions are, as already mentioned, equivalent to the well known Types III. and IV.

It will give some idea of the scope of Mr. McClean's work to mention that in the region A he has photographed 35 stellar spectra, in B 31, in C 38, and in D 26, while in AA he obtained 30. The remaining regions were not to be studied until this industrious observer made his expedition to the Southern Hemisphere.

The photographs which were taken at Rusthall occupy 17 plates in the *Philosophical Transactions of the Royal Society for* 1898. In a work so extensive it is difficult to select a part for special notice. I may, however, venture to offer as a typical illustration of Mr. McClean's skill the plate marked C in the lower Galactic zone north. There we have the spectra of γ *Orionis*, Algol, and Rigel, while for comparison, Runge and Paschen's spectrum of Cleveite gas has been added.

The important labours of Mr. McClean in the exploration of the spectra of the brighter stars in the Southern heavens have now to be described. I am able to discharge this duty the more readily because he has himself provided an admirable account in his work entitled *Spectra of Southern Stars* (Stanford, 1898).

Recalling the method by which Mr. McClean divided the celestial sphere into eight regions, it will be observed that from Rusthall he was able to conduct the exploration of A, B, C, D, and AA; the three regions on which his attention had to be concentrated at the Cape of Good Hope are therefore BB, CC, DD. These are respectively the southerly halves of the upper Galactic zone, the lower Galactic zone, and the South Polar zone.

Mr. McClean worked at the Cape of Good Hope from May to November 1897. Northern astronomers will read with mingled feelings the record which Mr. McClean gives us of the purity of the skies in South Africa. It appears that during the six months on which he was engaged in his task he had no fewer than 76 perfectly clear nights in addition to many others which were partly suitable for refined astronomical work. He was thus able to obtain 292 photographs of stellar spectra, the total number of different stars being 116.

Dr. Gill placed at the disposal of his visitor the well-known astrographic instrument that has already been used with such energy and success at the Cape. In front of the object glass of this telescope Mr. McClean fitted his refracting prism of 12 inches in aperture and 20 degrees refracting angle. Thus the equipment with which his work was conducted in the Southern Hemisphere was practically identical with that which he had employed in the first part of his work at Rusthall. The advantage of this symmetry in the method of conducting the survey is obvious, and will be appreciated by every one who has occasion to use the two series of beautiful plates.

One of the most instructive facts that is brought out by the Tables in which the results of the observation are embodied, relates to the distribution of the stars of Division I., or, as Mr. McClean frequently designates them, the "Helium" stars. The features brought out fully justify the choice of that particular partition of the celestial sphere which he has adopted. It is obvious that these Helium stars are strewn not at all uniformly over the surface of the heavens. They are mainly congregated in

the two zones north and south of the Galactic Equator. This fact, now so clearly established, seems to point to some fundamental characteristics in the distribution of the sidereal masses on the nature of which perhaps it would be premature at present to speculate.

It should be observed that the remarkable tendency of Helium stars to appear condensed along the Galaxy is peculiar to stars of this particular division. Stars belonging to the other divisions do not seem, so far as Mr. McClean's lists inform us, to exhibit any similar relation to the Milky Way. For example, the stars of the solar type seem to appear with fairly uniform frequency over all the eight regions of the sphere, and a like statement may be made with regard to the stars of the remaining types.

It was, I believe, Sir John Herschel who first drew attention to the fact that the sidereal objects in the southern heavens considerably surpass in interest, in variety, and in splendour, the objects with which astronomers in our Northern Hemisphere are so familiar. An illustration of the truth of this principle may be derived from an examination of the distribution of the Helium stars as set forth in Mr. McClean's tables. Not only are the stars of this particular class concentrated in the immediate neighbourhood of the Galaxy, but they are largely confined to a particular part of that luminous girdle just as a group of Wolf-Rayet stars is found in *Cygnus*. It unfortunately happens, at least so northern astronomers will think, that the regions of the Galaxy where the Helium stars most delight to congregate are precisely those parts of the Galaxy towards which their spectroscopes can never be directed. Mr. McClean remarks how this feature in the stellar distribution may be strikingly shown by marking off the Helium stars in the Key Chart of *Gould's Uranometria Argentina*. From *Perseus*, through the south to *Sagittarius*, the Helium stars are almost entirely congregated within the limit of the Galaxy.

In the work I have already cited will be found certain tables in which Mr. McClean has collected the result of his labours into a concise form full of interest and suggestiveness. In some of them he has included figures derived from his labours at Rusthall, so that in many respects these tables present a survey of the complete heavens. Thus we find that there are, in all, no fewer than 88 stars of Division I., not of course going below the standard limit of the $3\frac{1}{2}$ magnitude. The unequal distribution of these stars, to which we have already referred, is well brought out by the fact that while no more than 18 are to be found in the North and South Galactic Polar regions, no fewer than 70 lie in the two zones on either side of the Galactic Equator. The doctrine of probability assures us that it can be no mere accident which permits one-half of the celestial sphere to have almost four times as many of these particular objects as are contained in the other half.

But the table which perhaps most specially illustrates our medallist's work in the Southern Hemisphere is that containing an elaborate comparison between the spectrum of the celebrated star β *Crucis* and the spectra of Helium, Hydrogen, and Oxygen. In this table he has recorded the result of the measurements of the photographs which are to be seen on Plate 12.

About 100 lines in the spectrum of β *Crucis* are set forth. These lines have been measured on the plates in the usual manner, and then these measurements have been transformed into wave-lengths from their original expression in millimetres. For this transformation formulæ of interpolation have been employed. Each formula involved four constants, and for the determination of these constants four characteristic lines of Helium have been taken as standards. The wave-lengths of these standard lines being known from Rowland's scale, the four constants of the formulæ were determined. By substitution in the formula of the scale position of any other line its wave-length was therefore known. Mr. McClean has set down in his table the wave-length thus ascertained of the several lines in the spectrum of β *Crucis*.

The agreement between the lines of Helium in the spectrum of this star and the lines measured by Runge and Paschen in the spectrum of the same element obtained from terrestrial sources, are very remarkable. There are about 20 lines common to the two spectra, and the residual differences between the determinations of their wave-lengths are insignificant. The range of these lines, adopting the usual method of representation, vary from wave-length 380·59 up to 492·21. There is also a comparison of the lines in the spectrum of Hydrogen, as determined by Ames, with certain other lines in the spectrum of β *Crucis*. Here again the agreement is satisfactory.

But more than half the lines in the spectrum of this particular star form what Mr. McClean calls the *extra* lines. They belong to neither Hydrogen nor Helium, and the claim made for their interpretation is perhaps the most characteristic feature of this part of Mr. McClean's work. With the object of accounting for these lines, Mr. McClean gives, in a special column, the wave-lengths of lines characteristic of the spectrum of Oxygen as observed by Neovius. Between forty and fifty of these lines appear from this table to agree well with lines in the spectrum of β *Crucis*. I may take as examples of the series both the first and the last. There is a line in the star spectrum whose wave-length as determined by the formula of interpolation is 407·02. This is naturally compared with an Oxygen line that falls according to Neovius at 407·01.

A table on page 14 of Mr. McClean's work must, however, be consulted in connection with the interesting interpretation which he proposes for these extra lines. A list is there given of lines attributed by Neovius to Oxygen, but apparently absent from the spectrum of β *Crucis*. This important subject merits

most scrupulous examination by spectroscopists, and to their consideration may be commended the words of our medallist, that :

"Taking everything into account, the succession of coincidences between the extra lines of *β Crucis* and the Oxygen spectrum can only be accounted for on the basis of the extra lines being in the main actually due to Oxygen."

Astronomers will turn with special interest to learn what Mr. McClean's researches at the Cape have disclosed with reference to that particularly interesting star *γ Argus*. The photograph of its spectrum on Plate 12 shows in a striking manner the bright lines characteristic of this typical Wolf-Rayet star. The spectra of *β Crucis*, of *β Centauri*, and of *β Can. Maj.*, which are placed in juxtaposition, fully justify Mr. McClean's announcement that *γ Argus* is also to be regarded as a Helium star. Towards the close of this volume several statements occur that will have a still further interest for astronomers, inasmuch as they seem to point to the unlimited fields of work opening up before those spectroscopists of the future who may have the happiness to work in Southern climes. I may mention, in illustration of this remark, that Mr. McClean has found several cases in which the two components of a Double Star are each of the Helium type. We also learn that a fine Helium star in *Argus* is accompanied by a group of small Helium stars, while he further tells us that a small group of Helium stars are adjacent to *π Argus*, a solar star.

It is impossible for me on an occasion like the present to forbear from any mention of the splendid benefactions by which Mr. McClean has also striven to further the cause of astronomy. As founder of the Isaac Newton Studentships at Cambridge, and as donor of the magnificent photographic telescope at the Cape, he has rendered services to the advancement of astronomy of which this generation is already reaping the fruits, and which will be even more useful in the generations to come. But I need hardly inform you that the award of this medal has, in the view of the Council, been made in recognition not of Mr. McClean's position as a splendid patron of our science but in recognition of his position as a faithful toiler in our ranks. We know that, disdaining to live a life of inglorious ease, he has elected to follow with vigour, with skill, and with success, an arduous and difficult branch of astronomical work.

Let it be also noted that in the performance of his great task Mr. McClean did all the work himself. He employed no staff of assistants. He had not even a single assistant to lighten his labours in his laboratory by day or to relieve him in the observatory by night. Those long vigils in both hemispheres were not, I can assure you, observed by deputy. Your medallist was not content with merely designing the arrangements for the survey. Every detail of the work he has carried through himself. It was he that exposed those plates to the heavens through the long silent hours of darkness. The critical duty of developing those

plates was never entrusted to any other hand than his own. He it was who subsequently gave the enlargement necessary for publication; it was his eye that measured the lines, and his was the pen that worked out the calculations. Need I add more to prove that what Mr. McClean's hand had found to do he did with all his might. The lofty principle that inspired his work was the love of truth, and we are assembled here to-day not less to do honour to the spirit in which his work was undertaken than to do honour to the work itself.

In the name of the Royal Astronomical Society, I therefore hand this gold medal to Mr. McClean as the visible token of our admiration for his spectroscopic survey of stars in both celestial hemispheres.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:

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